ORGANIC LIGHT-EMITTING DIODES

LIGHTING TOWARD A SUSTAINABLE ENVIRONMENT

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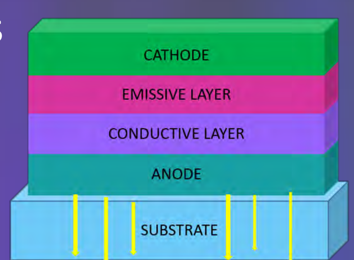
Background

OLEDs are flexible and ultrathin area light sources that can be produced as large sheets. Versatile and portable, potential uses include direct application to clothing, as displays in glass windshields, and as self-illuminating TVs.

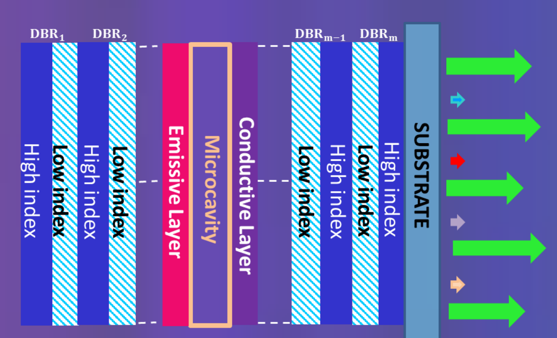
Within an OLED, there are emissive and conductive layers sandwiched between an anode and a cathode. The emissive layer has extra electrons and the conductive layer has extra “holes”. When a voltage is applied, electrons flow from the cathode to recombine with holes in the emissive layer, thus producing light. In order to produce various colors of light, different materials are used in the emissive and conductive layers. This research project focuses on changing the parameters of a simulated OLED and analyzing the effects of these changes on OLED emission patterns. Programs written in MATLAB modeled the layers of the OLED simulation and imitated a micro-resonator cavity and distributed Bragg reflector mirrors (DBRs) comprised of various materials. By changing the parameters of the microcavity and the DBRs (devices that amplify light), the emission patterns were altered. Through this study, it is possible to engineer an OLED that can maximize the emission pattern of the model.



Basic OLED structure

Method

The microcavity and DBRs are multi-layer optical structures that have specific refractive indices. The refractive index is defined by the speed of light in vacuum divided by the speed of light in the material, and it is used in calculations of the electric and magnetic fields; in this study, light is observed in the form of an electromagnetic wave.



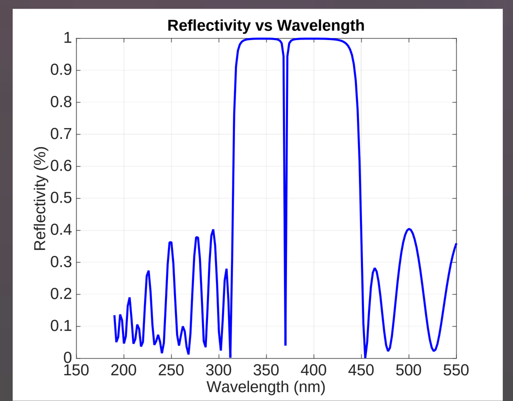
Visual representation of the OLED simulation

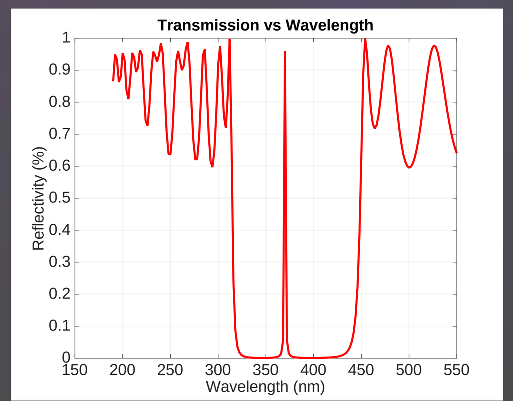
In order to calculate the values of the reflection and transmission, it is necessary to first calculate the characteristic matrices of the layers in the OLED. A characteristic matrix is a 2x2 matrix that contains the real and imaginary values of the electric field and the magnetic field. There are three characteristic matrices: one for the upper DBR, one for the lower, and one for the microcavity. With these matrices, the total characteristic matrix, M_{Total}, is calculated using the following equation:

$$M_{Total} = M_{DBR_1} * M_{Cavity} * M_{DBR_2}$$

M_{Total} is also a 2x2 matrix. For use in the equations for reflection and transmission, the top and bottom two elements of the matrix form two complex numbers, denoted as B and C, respectively. Thus, it is possible to calculate the reflection and transmission, given by:

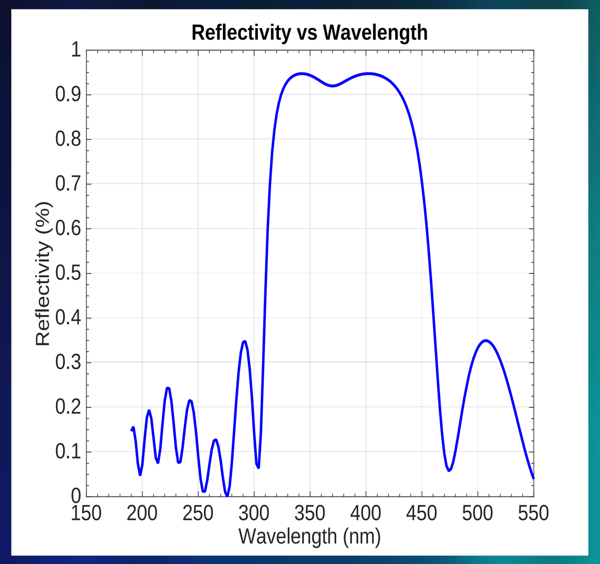
$$R = \left(\frac{y_0 * B - C}{y_0 * B + C}\right)\overline{\left(\frac{y_0 * B - C}{y_0 * B + C}\right)} \qquad T = \frac{4y_0 Re(y_{sub})}{(y_0 * B + C)\overline{(y_0 * B + C)}}$$



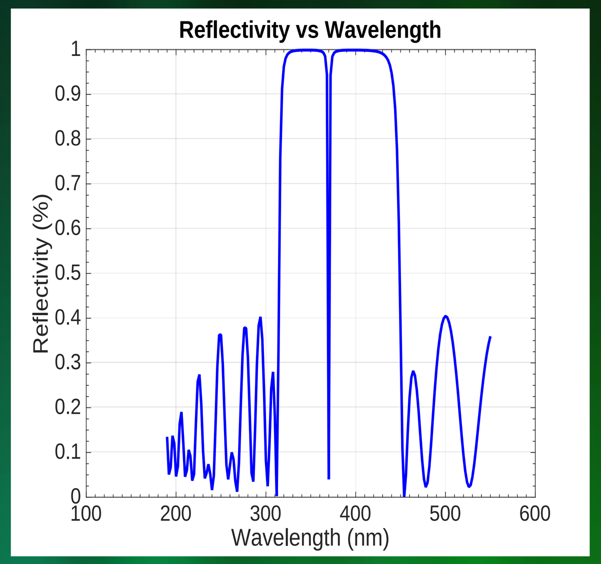


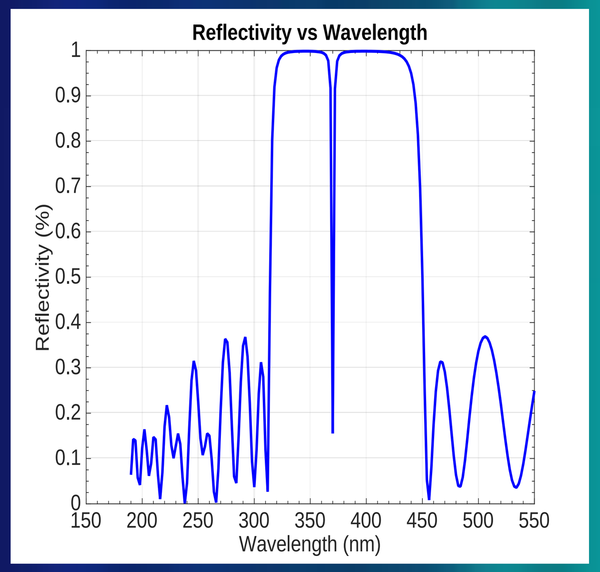
Results

Before / After

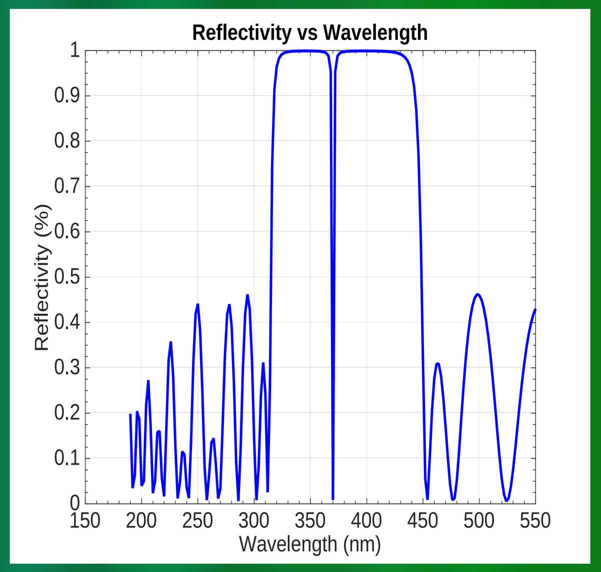


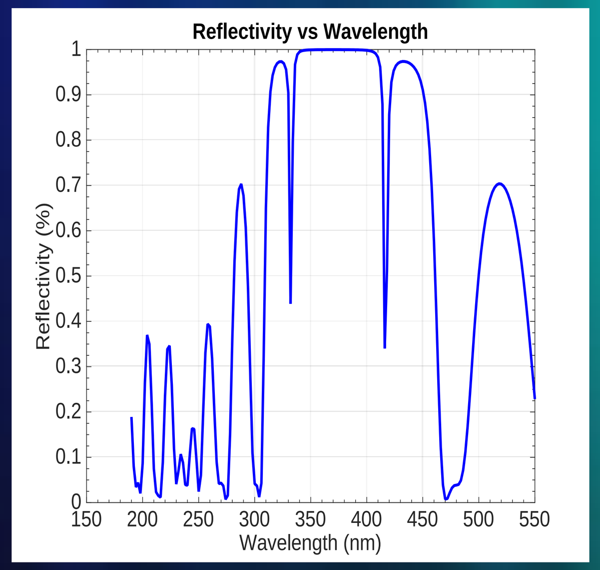
Changing the number of DBR stacks above and below the cavity allows for high transmission.



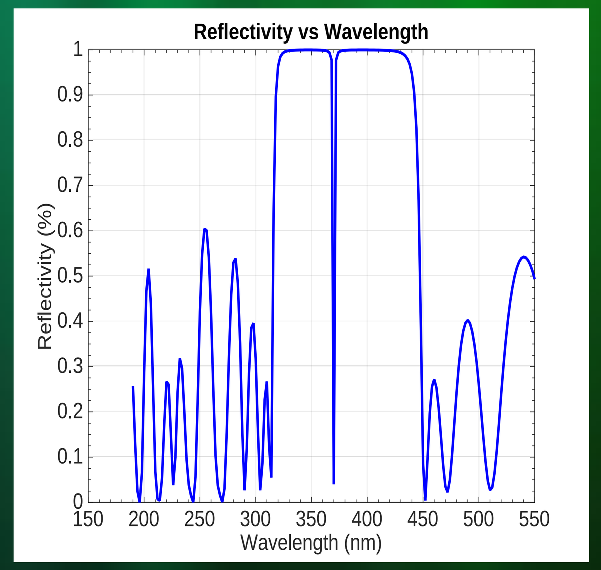


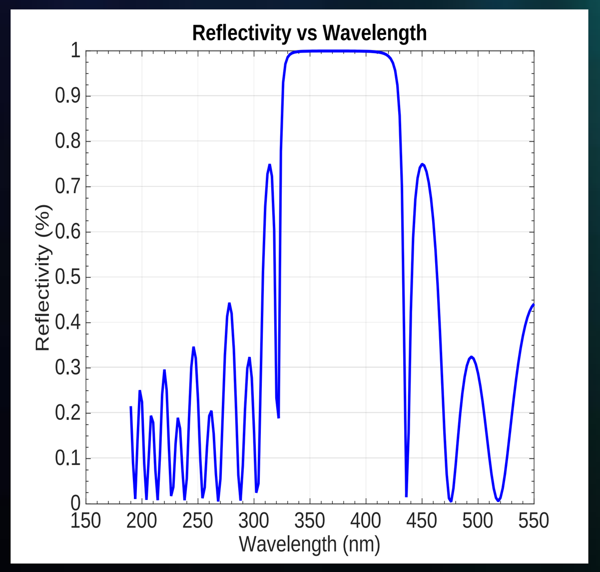
After parametric studies of different substrate indices, it was determined that a substrate index closer to 1.0 increases the transmission.



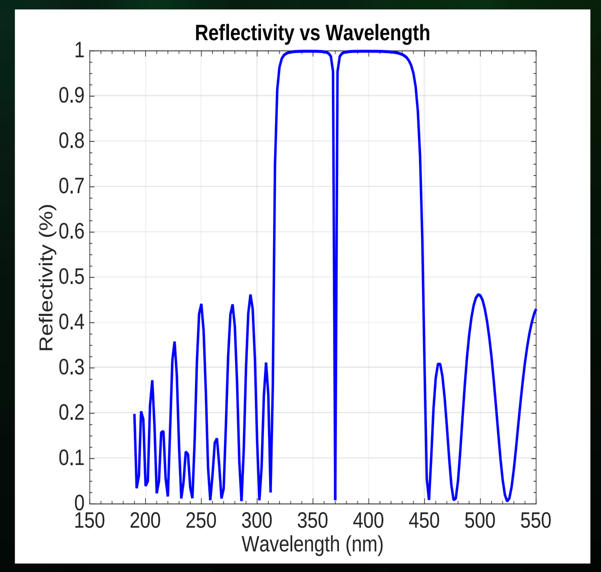


Through trials, this research has shown that a cavity index close to an integer causes high transmission.





Cavity lengths equal to half or one quarter of the Bragg wavelength produce transmission at the specified wavelength.

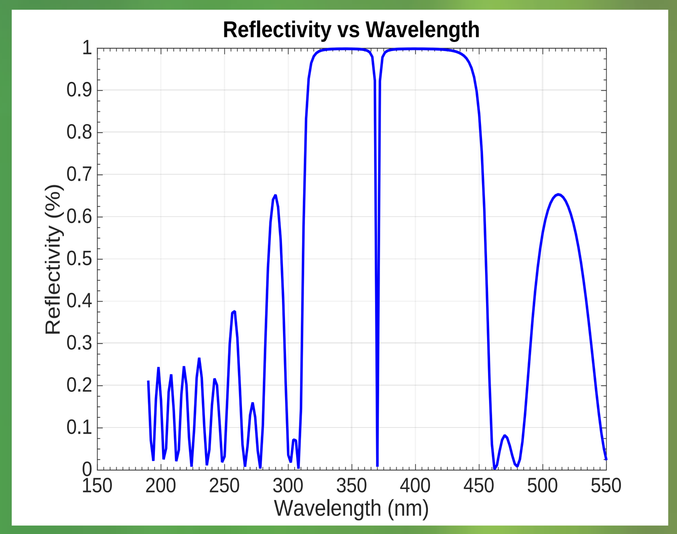


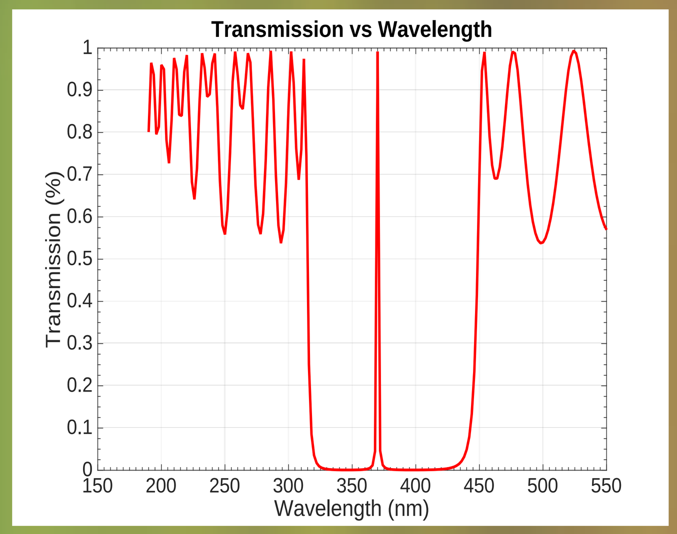
Conclusion

Based on the analysis of various emission patterns, an OLED works best when it meets these four criteria:

1. Having the same number of stacks above and below the microcavity increases transmission.
2. A small substrate refractive index (closer to 1.0) increases the transmission.
3. The closer the microcavity refractive index is to an integer, the better the transmission. Conversely, the further the microcavity index is from an integer, the worse the transmission.
4. The cavity length should be half or one quarter of the Bragg wavelength for best transmission.

Final Results





This combination of the microcavity and the DBRs’ properties increases the transmission of light at the specified Bragg wavelength. It also allows for the transmission to reach nearly 100% (precisely 99.2%). All of the elements are imperative for high transmission and specified reflection; without the microcavity, there is negligible transmission, and instead, maximum reflection due to the DBRs. By following these parameters, there is the potential to create an improved OLED that will emit a precise color of light with enhanced color-brilliance and brightness.

References

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Acknowledgements

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